NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSC APOLLO 13 INVESTIGATION TEAM

FINAL REPORT

PANEL 5B

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CORRECTIVE ACTION STUDY AND IMPLEMENTATION

FOR

LUNAR MODULE

MAY 1970

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

MSC APOLLO 13 INVESTIGATION TEAM

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FOR
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PANEL 5B

Corrective Action Study and Implementation

Lunar Module

Purpose of Panel

Panel 5B was created to evaluate the need of corrective action and proposed hardware implementation as required. This panel reviewed the results of other panels, primarily the Spacecraft Incident Investigation and the Related Systems Evaluation to determine the desirability of conducting specific studies. These studies will be defined in detail to the contractor and coordination and review of the results managed by the panel. After completion of the various reviews, appropriate hardware implementation action will be prepared for disposition by the Apollo Configuration Control Board.

Summary

Members of Panel 5B met with Panel 6 on May 18, 1970, to review the first draft of Panel 6 conclusions and recommendations. Specifically, there were no recommendations for LM hardware change. During the discussions it became apparent that there are items that require further study. These items are discussed in the following paragraphs.

1. Descent Stage Propellant Quantity Gaging System (PQGS)

The only area in LM pressure vessel systems identified as normally having oxidizer, nonmetallic materials, and an energy source together is the descent stage propellant quantity gaging system (PQGS). The PQGS is a capacitance measuring device which normally dissipates 1 to 10 microwatts of energy to the fuel/oxidizer. Normal operating current supplied to the sensor electronics is 54 ma at 20.5 volts (1.1 watts). The device is current-limited to 300 ma. Single-point failure analysis has shown that a failed PQGS cannot provide the electrical energy required to induce tank failure. Teflon and Rulon used in the PQGS are exposed to the fuel/oxidizer. Further compatibility testing of these materials is being conducted. Grumman Aerospace Corporation has been requested to investigate alternate materials for each. No failures of the types postulated have ever been experienced on the program.

2. Ascent Stage Propellant Low-Level Detector

The case of the ascent stage propellant low-level detector (APS PLD) isolates the electronics from fuel and oxidizer during normal operation. A case failure of the completely enclosed electronics of this device would expose the electronics to fuel/oxidizer. Worst case energy input under the conditions would be 7 watts. The device is current-limited to

250 ma by a fuse. The propellant level detector has never experienced any applicable failure, suggesting fluid breakthrough or excessive fluid heating due to electronic failure. Its intended purpose is to give warning to close the RCS interconnects due to impending propellant depletion, but this is presently cued by APS burn procedure timeline. Present requirements for the APS PLD should be evaluated and the units removed if necessary. Future mission plans could incorporate a short-time rendezvous that necessitates restart of the ascent engines and the low-level detector will be required.

3. Loss of Thermal Shields

Complete loss of thermal protection around the gaseous helium tanks coupled with direct solar impingement could cause burst pressures in the tanks; these tanks do not have pressure relief provisions. Undetected failures modes which would cause the complete loss of thermal protection are considered extremely improbable with the most probable being internal overpressure due to inadequate venting of the shields . If this case occurred, the failure would be a rupture in the blanket (delta of 0.1 psid) which would relieve the pressure before the blanket could be pulled loose from the standoffs. Grumman has been requested to investigate the additional protection which could be provided by a thermal overwrap of the tanks.

4. Batteries

As a result of the battery investigation it was revealed that batteries have not been considered as pressure vessels and, therefore, were not burst-tested as part of the development or qualification program. There is an inconsistency in the case of the pyro/ED battery in that the case is leak checked to only 15 psi and then a 30 $\pm$ 5 relief valve is installed. Therefore, case pressure integrity is not demonstrated to relief valve capability. Prior tests indicate that the burst would be a pressure relieving split and not an explosive burst. MSC will conduct burst tests on all spacecraft batteries. A modification of the acceptance pressure test of the batteries is being investigated by Grumman.

5. Pressure Transducers

Pressure transducers have not been considered pressure vessels and, therefore, have not been burst-tested. However, these devices, which are used in the GOX and propellant systems, are acceptance tested to 1-$\frac{1}{2}$ times design operating, and design burst is 5 times operating pressure. Investigation has centered around postulating a leaking diaphragm which would cause the tank fluid to come in contact with nonmetallic materials and an energy source. Calculations by Grumman have shown that assuming a leak and combustion, there is enough energy in the materials in the cavity to rupture the transducer structure. There are two types of transducers used - one a Bourdon tube device (-601) and the other a diaphragm/strain gage device (-624).

Assuming electrical failures, the energy available in the cavity differs slightly.

The -601 maximum operating current is 1.0 ma at 28 vdc maximum power which could be drawn assuming single-point failure is 200 ma, at which time a 147-ohm resistor would open. Maximum sustainable current for the resistor is 60 ma, which results in 1.6-watt heat dissipation.

The -624 maximum operating current is 10 ma at 28V. Assuming single-point failure, the maximum current that could be drawn is 0.15 a, at which time a 221-ohm resistor would burn open, terminating the current flow. The highest sustainable current is 46 ma, which causes 1.3 watts of heat.

Grumman is currently investigating whether these postulated conditions could cause combustion. Tests on materials present in the cavity will be conducted at WSTF in the presence of GOX and propellants. Possible transducer tests with failed diaphragms are being considered.

Grumman states that this class of transducer has never incurred any applicable failure, suggesting fluid breakthrough or excessive fluid heating due to electronic failure.

6. <u>Temperature Sensors</u>

The case of the immersion temperature sensor used in the propellant systems completely isolates the electronics from fuel and oxidizer during normal operations. A case failure of this device would expose the electronics to propellants. Normal operating power of this device is 0.5 ma at 8.5 vdc. The maximum power that can be delivered as the result of circuit failure is 0.0085 watts. Grumman is currently investigating whether these postulated conditions could cause combustion. Grumman states that this class transducer has never incurred any applicable failure, suggesting fluid breakthrough or excessive heating due to electronic failure.

Conclusions

At this time it does not appear that there is any reason to change LM configuration or procedures. However, the investigations and tests mentioned should be completed and final conclusions formulated. If results indicate potential hardware change, the proposed changes will be immediately expedited to the Configuration Control Board.

Recommendation

The recommendations of the panel were as follows:

1. No modifications to LM hardware or procedures are recommended at this time as a result of this investigation.

2. MSC should continue investigating the desirability of inerting the ascent stage propellant low-level detector and report recommendations to the Configuration Control Board.

3. MSC should continue investigating possible tank thermal wrap and report recommendations to the Configuration Control Board.

4. MSC should run battery-case burst tests and investigate reasonable ATP changes and report recommendations to the Configuration Control Board.

5. MSC should continue failure-modes investigations and possible failure tests of pressure transducers and report recommendations to the Configuration Control Board.

6. MSC should continue nonmetallic-materials testing at WSTF for transducer cavity materials in the presence of GOX and propellant and report findings and recommendations to the Configuration Control Board.

7. Nonmetallic materials which have been certified for O_2 application by the MSFC ambient pressure LOX tests should be certified using the WSTF GOX test at operating pressures as rapidly as possible.